Interim Progress Report

Award No.: NA17FX1415

Grant Program/CFDA#: 11.439 Marine Mammal Data Program

Recipient Organization: University of Alaska Fairbanks, Institute of Marine Science

Principal Investigators: Evelyn Brown*, Susan Hill, Richard Collins, Robert Foy
* contact for correspondence

Project Title: Comparison of Prey Availability and Ecology in Steller Sea Lion Foraging Regions: A Coordinated Aerial Remote Sensing Study

Funding: Federal: $ 763,147 **Match:** $240,000 (Federal Holdback-NOAA Environmental Technology Laboratory, Boulder CO)

Award Period: From: July 1, 2001 To: June 30, 2003

Period Covered by This Report: From: July 1, 2001 To: January 31, 2002

Brief Summary:

This proposal addresses six research priorities and is coordinated with ongoing shipboard sea lion research programs in three areas in Alaska (Kodiak, Lower Cook Inlet, and Southeast AK) during two time periods (late spring, late summer). The overall objective is to compare synoptic marine ecological information between two sea lion foraging regions over large spatial regions at three temporal scales (diurnal, seasonal, inter-annual), supplementing data from the existing surveys. One region (Southeast Alaska) has a healthy population and the other (Kodiak) has a population in decline. The secondary objective is to cover regions not accessible by ship in the extreme nearshore and upper surface (< 5 m) and to extend coverage beyond ship transects. Using airborne remote sensing instrumentation (including lidar, IR radiometer, ocean color video, high resolution digital video, and IR video), we will map ocean fronts, chlorophyll, zooplankton, fish prey resources, fish and marine mammal predators, predator/prey interactions (foraging bouts), and human activity in the upper 50 m of the water column during the day and night. We will use shipboard results for signal validation, interpretation, and to estimate detection probabilities (sub-attenuation correction factors). We will produce 3-d visualizations of the results, link aerial to satellite data, and perform geostatistical analysis for interpretation. We require collaboration from the NOAA ETL lab in Boulder to provide instrumentation and personnel for airborne surveys and signal processing.

The main goal for this project is to provide ecological information needed to directly answer questions concerning available prey resources, predator/prey relationships, and

changing environmental conditions. Two hypotheses will be addressed in analysis (see Program Summary). This will be accomplished by the following objectives:

1. make near-synoptic comparisons of two very different sea lion foraging regions on a variety of spatial and temporal scales
2. expand coverage to areas not accessible by ship in the extreme nearshore and upper surface (< 5 m)
3. expand coverage to areas beyond ship transects
4. determine statistically significant differences in prey availability, predator/prey relationships, and ecosystem structure between day and night, critical and non-critical habitat, the two seasons and the two areas

The secondary goal is to provide data to other researchers used to answer other research questions concerning marine mammal predation, fisheries interaction/localized depletion, and population counts. The objective is to create a data archive accessible through web browsers.

The tasks required for completion of the goals and objectives are:

1. Assemble the instrumentation package in a unique day versus night mounting, power and control system designed to operate from a twin-engine aircraft
2. Coordinate with UAF and NMFS cruises in Kodiak and southeast Alaska in late spring and late summer to assure synoptic data collection
3. Set up close communications with satellite tag project leaders and ship surveys to enable adaptive response (within the survey dates) to tagged animal locations
4. Collect airborne data
5. Signal process, validate, interpret, and map instrument data
6. Link instrument data to synoptic shipboard, available sea lion diet, satellite tag, and satellite image data
7. In collaboration, interpret the collective information collected in an ecological sense;
    a. Describe general distribution patterns of plankton, fish, and predators
    b. Determine the spatial relationships of the biological features to one another
    c. Describe ocean structure in terms of chlorophyll, SST-SSS (from ship data), and ocean fronts.
    d. Determine how the biological structure is related to the ocean structure
8. Compare the patterns, spatial relationships, and ocean structure between the two regions, between day and night, between May and July, and between the two years.
9. Archive instrument data to a web linked database
10. Report on the results via scientific meetings and publication.

Summary of Progress and Results:

Objectives 1-3 and tasks 1-5 apply for this reporting period.

For the completion of task one, a Beech King Air twin turbine A90 was chartered through Airborne Technologies Inc. (Wasilla, Alaska) and flown from Virginia (point of origin) to Alaska on July 15. The aircraft was modified, prior to leaving Virginia, to provide two separate camera points (36.6 by 40.6 cm and 30.5 by 30.5 cm; Figure 1). The instrument package and mounts were assembled on July 16 and 17th in Wasilla consisting of a lidar (FLOE system from ETL, Boulder) for mapping subsurface features, an infrared radiometer for measurements of SST, a high resolution RGB imager for measurements of ocean color and mapping surface features, and a high resolution CIR (thermal infrared) imager for mapping thermal structure, birds and mammals at night. Rack mounts were constructed for housing the lidar/IR radiometer downlooking through the rear hole and the two imagers downlooking through the front hole (Figure 1). The lidar and imagers were configured to transmit and collect signals at a 10 degree angle in the same direction, to minimize backscatter interference and glare and to provide 100% overlap in data collection. Two GPS systems were mounted with one system used for aircraft navigation and one to integrate with the instruments and provide 1 second geocoding recorded with the digital information. The two GPS systems were synchronized and co-calibrated prior to flights.

For the completion of task 2, ship survey schedules were obtained from Bob Foy, UAF FITC in Kodiak survey Eastern Kodiak, Ann Hollowed and Chris Wilson, NMFS AFSC out of Seattle also surveying Eastern Kodiak, and Mike Sigler, NMFS Auke Bay Lab, Juneau, surveying in Northern Southeast Alaska. The attached flight schedule (Table 1) was formulated in early July based on those communications.

For task 3, discussions with Tom Loughlin and Brian Fadely (NMFS Sand Point Lab) led us to establish two point contacts for obtaining satellite tag information in order to focus some effort at the actual location of tagged animals. Kate Wynn was our contact in Kodiak while Brenden Kelly (UAF SFOS Juneau Center) was our contact in Southeast Alaska. Neither individual received any satellite tag information during the course of the field season and we were therefore unable to complete this task. However, in retrospective discussions with the satellite tag project leaders, we inadvertently covered the areas used by tagged animals. However, the timing of our surveys and the use of the areas by the animals was not synoptic.

For task 4 and 5, we flew of 124.7 hours including aircraft ferry time to and from Virginia and mapped the lidar files collected. The flight schedule and hours flown each day are shown in Table 2. During the month of July, we flew 9 surveys, 4 during the day and 5 during the night. For day-night pairs, the same flight path was flown within the 24 hr period in order to do a true diel comparison. Figure 2 shows the flight paths for the day and night surveys; each individual mark in the figure represents a data file approximately 2000 shots long which represents a distance of approximately 4 km, assuming a flight speed of approximately 130 knots. During the month of August, we flew 13 surveys, 7 during the day and 6 at night. As in July, day-night pairs were matched in survey track during a 24 hr period. Figure 3 shows the flight paths and the concentration of effort in the Chiniak Gully (northern concentration) and Barnabas Gully (southern concentration). However, we collected a fair amount of information over the shelf between the two gullies, an area that the ship was not able to work. During the month of September, we flew two daytime surveys in Stephens Passage and Frederick Sound (Figure 4). During the first night flight (Sept. 11-12), we experienced a mechanical problem and returned to the base. However, the terrorist attack resulting in grounding the aircraft and we were not able to complete the September field season as a result.

We were not able to complete task 5 for reasons that will be described in the next section. However, we completed some preliminary processing to illustrate the information included in the signal data.

For the July broadscale survey, we identified 1000 shot (half) files, representing approximately 2 km along track, that included two general feature types: plankton layers and fish aggregations. The layers are identified as signal (total return minus background at depth) that persists over several thousand shots, that occurs gradually in the shot profiles, and that is characterized by smooth "bulges" in the shot profiles. School aggregations are identified as signal that generally persists over only a few shots, that occurs suddenly in the shot profiles, that can be characterized as "spikey", and for which a very strong signal (compared to layers) is returned. The distribution of 2 km bins that included signal interpreted as fish and/or plankton layers was plotted for day versus night flights (Figure 5). During the day, we identified 70 bins with fish and 81 bins with layers. During the night, 57 bins contained fish while 413 contained layers. The most notable differences were the abundance of fish in Marmot and Chiniak Bays (NE Kodiak) during the day but lack of any feature during nighttime. Plankton layers appeared along SE Kodiak in a nearly continuous band at night, possibly representing the concentration of vertical migrators, such as large copepods and euphausiids. During the day, plankton layers in this area were much patchier.

For the August survey, we show the results from a single survey conducted during the night on August 10 in Chiniak Gully. We plotted the variation in depth penetration, ranging from 20 to 50 m as well as the integrated signal from 0 to 25 m (Figure 6). The depth penetration along the flight path was estimated as the depth at which a threshold signal occurred. Because light attenuates with depth and attenuation varies with water body, at any given location there is a depth where signal cannot be discriminated from noise. The signal return at this depth is the threshold. In general, penetration was highest in the middle of the gully in water deeper than 100 m while penetration was lowest next to the coast or at the edges of the gully. The integrated signal, represented as the total signal between 0 to 25 m in depth, was also variable but highest in the center of the gully in areas over 20 km offshore (Figure 6). Each file was binned at 1 m depths to examine variation in signal by depth. Over the entire survey area, we plotted the average signal and the maximum signal observed at each 1 m depth bin (Figure 7). We observed that in Chiniak Gulley, during nighttime in mid-August, the mean signal peaked at 12 m while maximum signal peaks were observed at 9, 14, and 18 m depths in decreasing order of magnitude. The integrated and depth-specific signal was interpolated over a grid with 1000 m blocks and the smoothed surface plotted over the entire region (Figure 8). The hot spot was a concentration of targets approximately 20 km offshore in the center of Chiniak Gully. This hot spot occurred at all depths, but some depth-specific differences were noted. At the shallower depths (6 and 9 m shown), signal was also strong in nearshore areas in Chiniak Bay as well as at the edges of the gully. At the medium depths

(12 and 14 m), there was a swath of strong signal centering over the gully but expanding out over the edges of the gully in some areas. At the deepest depth shown (18 m), the signal was strongest at the hot spot and at the mouth of the gully crossing the 100 and 200 m isobaths approximately 50 km offshore. We will perform this type of analysis for all survey days and regions when the data set and data processing is completed.

Finally, we show an example of the thermal data collected with the thermal infrared imager. Figure 9 shows the thermal pattern visible in the surface water following the traverse of a whale. Although we have not matched the species identifications with the georeferenced data, this whale was either a grey or a humpback whale. These patterns have never previously been observed. Therefore the ability to map marine mammal distribution and movements, using this type of information, is ground-breaking science. We are currently developing pattern recognition software to enable us to identify and map the patterns observed in the dataset.

Problems

There were five problems encountered preventing the completion of tasks 3 and 5: 1) the inability to obtain satellite tag data in a timely manner, 2) the delay in recruiting a qualified student or hiring a research analyst to assist in signal processing, 3) the development of project-specific algorithms for the lidar and imager data, 4) the delay in receiving catch data needed to interpret the signals, and 5) the occurrence of the terrorist attack in September which resulted in a curtailment of our field season in Southeast Alaska. These problems have not resulted in a need for a project extension or additional funds.

For the first problem, we hope to resolve the communication issues at the PI meeting scheduled for late March. If we can establish a better in season communication system or regular electronic dumps to accessible ftp or web sites, we can obtain tagging information in a timely manner allowing surveys of tagged animal regions.

The second problem is due to the difficulty in finding qualified individuals. Beginning in July, we advertised a graduate student position and project, leaving the search open until late August. After receiving no applicants, we decided to hire an individual instead. The search for this individual has taken 6 months due to the lack of trained applicants and the need to expand the search. We are now in the process of hiring an individual and will have him (her) in place by late March. Currently we are short handed and have had to delay some of the processing tasks. We expect to be caught up with signal processing by June of this year.

The third problem resulted from a program decision to focus some initial energy on developing algorithms that will allow faster post-processing and bulk processing. This decision stemmed in part because of problem two. In particular, we are working on a more efficient method to separate signals from plankton versus fish and other large targets signals and flexible programs allowing files of variable size to be processed. In addition, some of the data, such as the thermal patterns, have never been encountered and we are experimenting with different software and pattern recognition algorithms in order to automate the process.

Finally, to date, we have received no catch or plankton data needed to interpret the signals. This is a common problem in large cooperative studies but we feel confident that the cooperating Principal Investigators are facing similar situations. We hope to discuss the trade of information at the upcoming meeting and develop a timeline. The lack of validation information will not delay signal processing and the initial analysis of spatial variability. We expect to obtain the catch information by the start of this field season.

Revised 2002 Schedule

We have decided to revise the 2002 schedule and allocate more flight time to Southeast Alaska in May (Table 1). This will allow us to compare Kodiak and Southeast during that month rather than July or August in Kodiak and Southeast in September. By September, day length has changed considerably over August, increased freshwater flow and storms result in a drastic change in the water column structure and therefore biological organization, and therefore, the comparison of structure during the August and September time periods is confounded by seasonal change. Because we were unable to complete our survey in Southeast in 2001, we feel it is vital to capture the comparison this year. During May, the weather is generally better, day lengths are longer and the comparison between the two areas is not confounded by seasonal differences since the surveys occur in the same month.

Report Prepared by Evelyn D. Brown, March 4, 2002

Table 1. The initial proposed survey schedule for aerial remote sensing coordination and revised 2002 schedule.

Date	Location	Objective	Ship/Ground Contacts
2001			
July 15-29	Kodiak	Offshore Foraging near Kodiak	Foy
Aug. 8-19	Kodiak	Pre-fishery Offshore/Bays	Hollowed/Wilson
		Nearshore Resources	Foy
Aug. 23-31	Kodiak	Post-fishery Offshore/Bays	Hollowed/Wilson
		Nearshore Resources	Foy
Sept. 4-21	SE	Nearshore/Offshore Foraging	Sigler
2002			
May 7-11	SE	Nearshore/Offshore Foraging	Sigler
May 10-20	Kodiak	Nearshore/Offshore Foraging	Foy
May 22-June 2	SE	Nearshore/Offshore Foraging	Sigler
July 15-29	Kodiak	Offshore Foraging near Kodiak	Foy, Wynne
Aug. 8-19	Kodiak	Pre-fishery Offshore/Bays	Hollowed/Wilson
		Nearshore Resources	Foy
Aug. 21-Sept.1	Kodiak	Post-fishery Offshore/Bays	Hollowed/Wilson
		Nearshore Resources	Foy
Sept. 4-21	SE	Nearshore/Offshore Foraging	Sigler
Revised 2002			
May 10-20	Kodiak	Nearshore/Offshore Foraging	Foy
May 21-June 3	SE	Nearshore/Offshore Foraging	Sigler
July 18-31	Kodiak	Offshore Foraging near Kodiak	Foy, Wynne
Aug. 8-31	Kodiak	Pre- and Post-fishery Offshore/Bays	Hollowed/Wilson
		Nearshore Resources	Foy

Table 2. Actual flight schedule flown during the 2001 field season.

Date	Description	Hobbs	Survey Total	Season Total	Route Flown	Comments
15-Jul	Ferry flight to Alaska	19.8	0.0	19.8	Transit	
16-17,Jul	Install equipment	0.0	0.0	19.8		
18-Jul	Palmer to Kodiak	2.0	2.0	21.8	Transit	Met with Bob Foy
19-Jul	Weather	0.0	2.0	21.8		Fog and rain
20-Jul	Day flight	2.4	4.4	24.2	North & East routes	Fog limited transects
21-Jul	Weather	0.0	4.4	24.2		Fog and rain
22-Jul	Day off	0.0	4.4	24.2		
23-Jul	Day & night flight	8.8	13.2	33.0	North & East routes	
24-Jul	Day off	0.0	13.2	33.0		
25-Jul	Day & night flight	9.8	23.0	42.8	Southeast route	
26-Jul	Day off	0.0	23.0	42.8		
27-Jul	Day off	0.0	23.0	42.8		
28-Jul	Night flight	1.8	24.8	44.6		Weather - cut short Wx
29-Jul	Day & night flight	4.9	29.7	49.5	Southeast route	Day flight cut short Wx
30-Jul	Day flight	4.6	34.3	54.1	Southeast route	
31-Jul	Kodiak to Palmer	1.8	36.1	55.9		Ferry flight
8-Aug	Palmer to Kodiak	2.0	38.1	57.9		Ferry flight
9-Aug	Weather	0.0	38.1	57.9		Evelyn to Kodiak am
10-Aug	Day & night flight	5.6	43.7	63.5	Chiniak	1st day attempt Wx out
11-Aug	Day & night flight	7.0	50.7	70.5	Barnabas	Good weather
12-Aug	Day off	0.0	50.7	70.5		
13-Aug	Day & night flight	4.9	55.6	75.4	Barnabas	Foy aboard, night flight fogged out
14-Aug	Day flight	1.1	56.7	76.5	Chiniak	Partial due to weather
15-Aug	Night flight	2.7	59.4	79.2	Chiniak	Night competion of Chiniak
16-Aug	Day off	0.0	59.4	79.2		
17-Aug	Day off	0.0	59.4	79.2		
18-Aug	Day flight	3.6	63.0	82.8	Chiniak	Day competion of Chiniak
24-Aug	Weather	0.0	63.0	82.8		
25-Aug	Day & night flight	3.5	66.5	86.3	Chiniak	Poor weather both night & day - partial
26-Aug	Day off	0.0	66.5	86.3		
27-Aug	Day off	0.0	66.5	86.3		
28-Aug	Day & night flight	8.8	75.3	95.1	Barnabas	Good surveys both day and night
29-Aug	Day off	0.0	75.3	95.1		
30-Aug	Ferry flight to Juneau	3.4	78.7	98.5		Wayne positioned A/C in Juneau
8-Sep	Day flight	3.4	82.1	101.9	Fredrick Sound	1st Juneau flight - good weather
9-Sep	Day off	0.0	82.1	101.9		
10-Sep	Day off	0.0	82.1	101.9		
11-Sep	Day flight	3.4	85.5	105.3	Fredrick Sound	2nd Juneau flight
12-Sep	Night flight	1.3	86.8	106.6	Fredrick Sound	Lidar equipment failure
13-Sep	Day off	0.0	86.8	106.6		Airport closed due to attack
14-Sep			86.8	106.6		Return aircraft to Palmer
23-Sep	Ferry flight to Virginia	18.1		124.7		

Figure 1. The remote sensing instruments shown mounted in the twin engine aircraft. Inside the aircraft, the dual RGB/CIR imagers controls and monitors are shown in the rack mount (top left) with the lens viewing through the camera port in the belly of the aircraft (bottom left). The rack mount for the lidar controls and power supply are shown (top right) with the laser head and receiving telescope mounted behind to send and receive through the rear camera port (bottom right).

Figure 2. Day (yellow) and night (red) surveys flown in Kodiak over the period July 20 to 30, 2001. These surveys were conducted in coordination with Bob Foy's broadscale ship survey over eastern Kodiak.

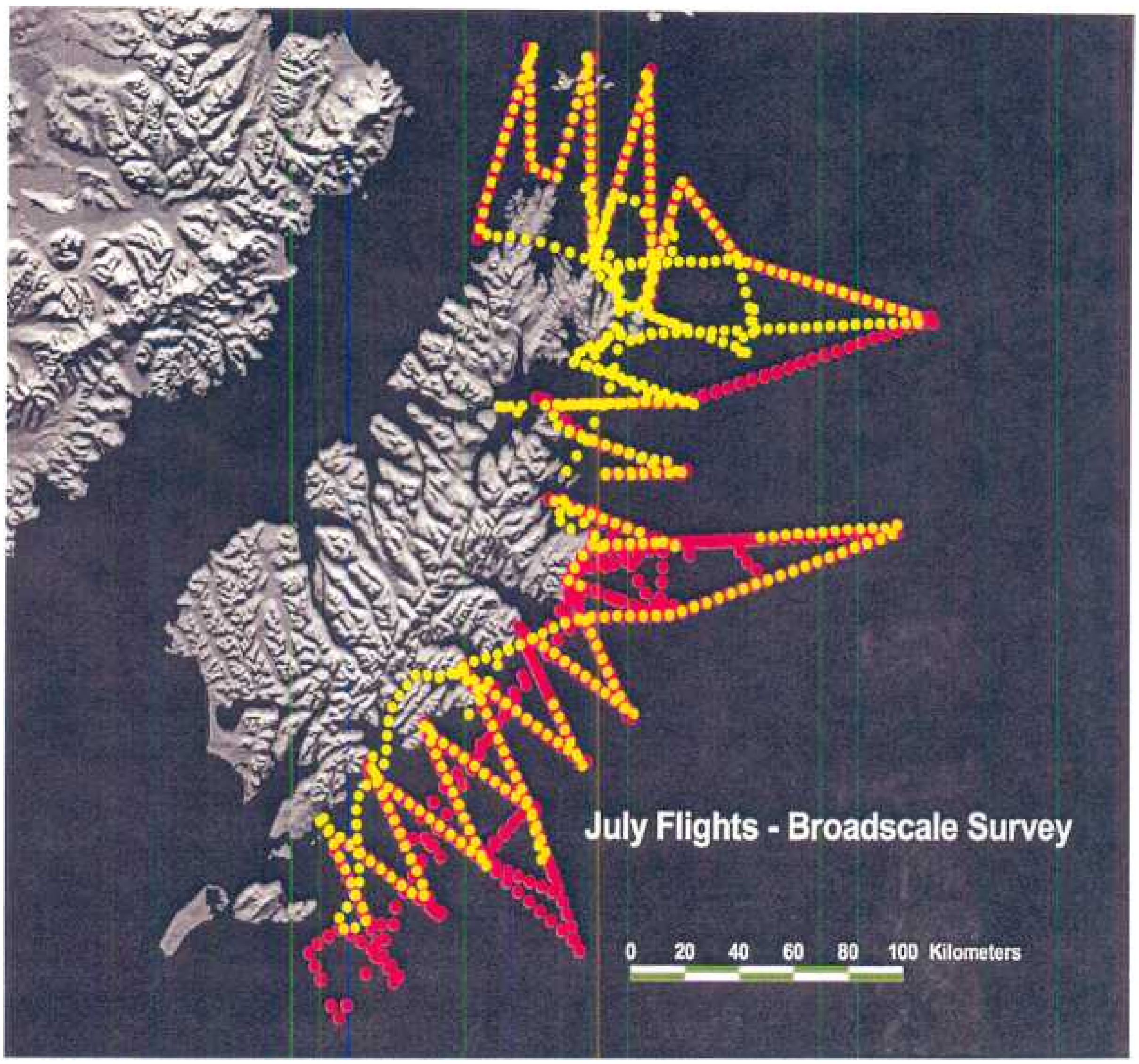

Figure 3. Day (yellow) and night (red) surveys flown over Chiniak and Barnabas Gullies off Eastern Kodiak Island from August 10 to 28, 2001 in coordination with the pre- and post-pollock fishery ship surveys conducted by Chris Wilson and Anne Hollowed.

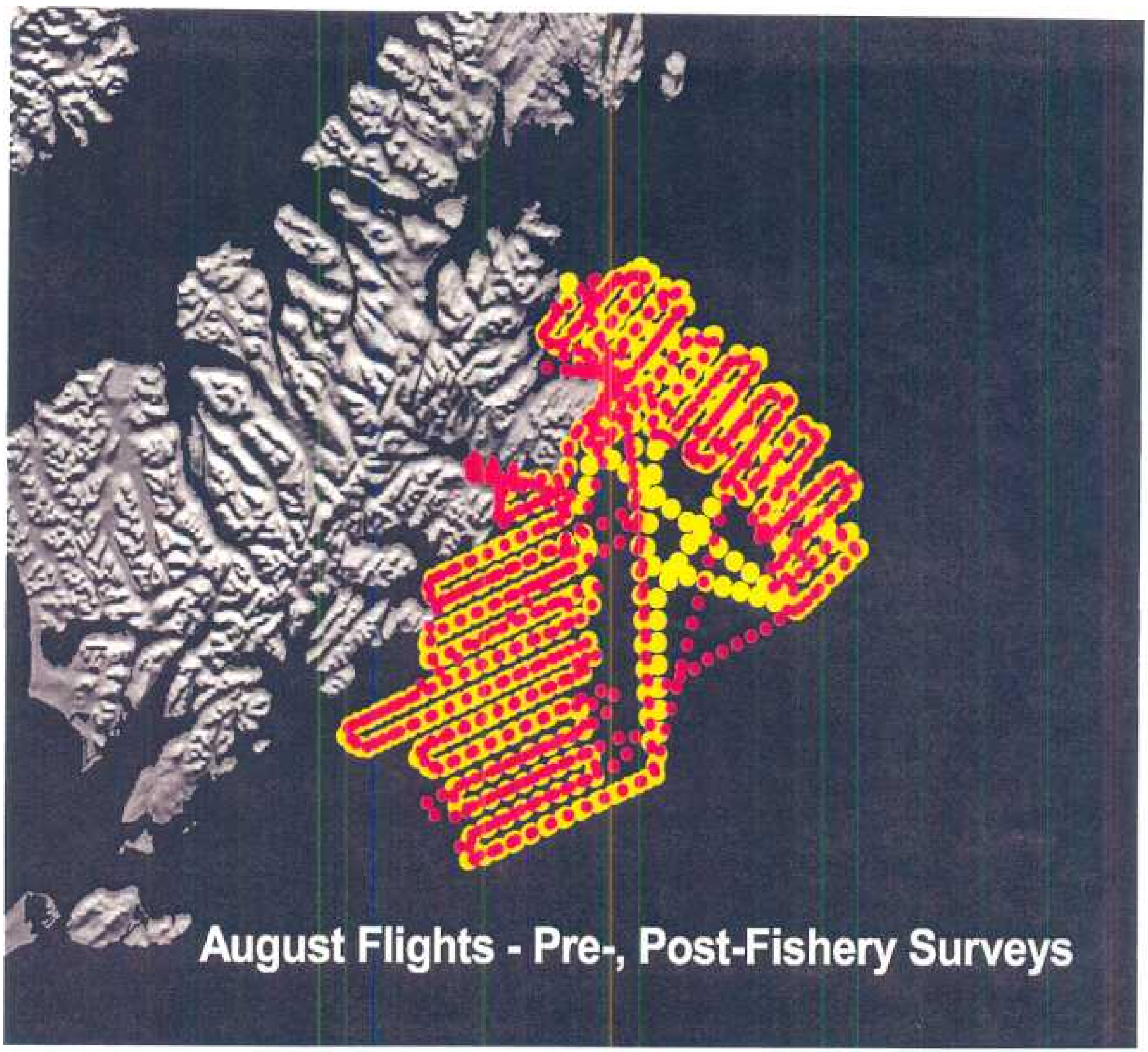

Figure 4. Day surveys flown over northern Southeast Alaska in Frederick Sound September 8-11, 2001 in coordination with the broadscale ship-board surveys conducted by Mike Sigler.

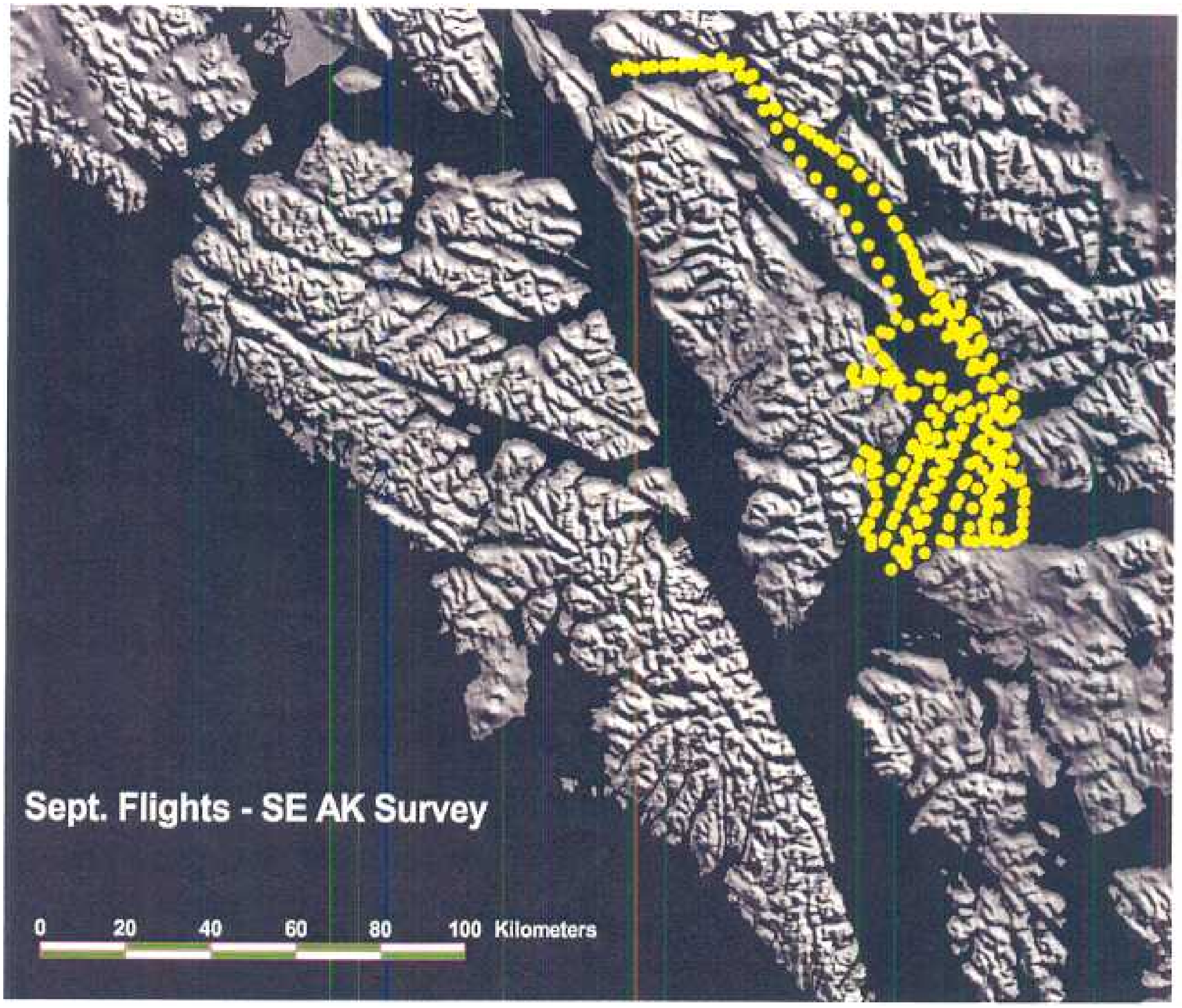

Figure 5. A day to night comparison in distribution of plankton layers (green circles) and fish aggregations (pink circles with diamonds) during the July survey period in Eastern Kodiak Island. Each day-night survey pair was completed within a 24 hr period. Each mark represents approximately 2 km along the survey track and indicates that the specified feature occurred within that area.

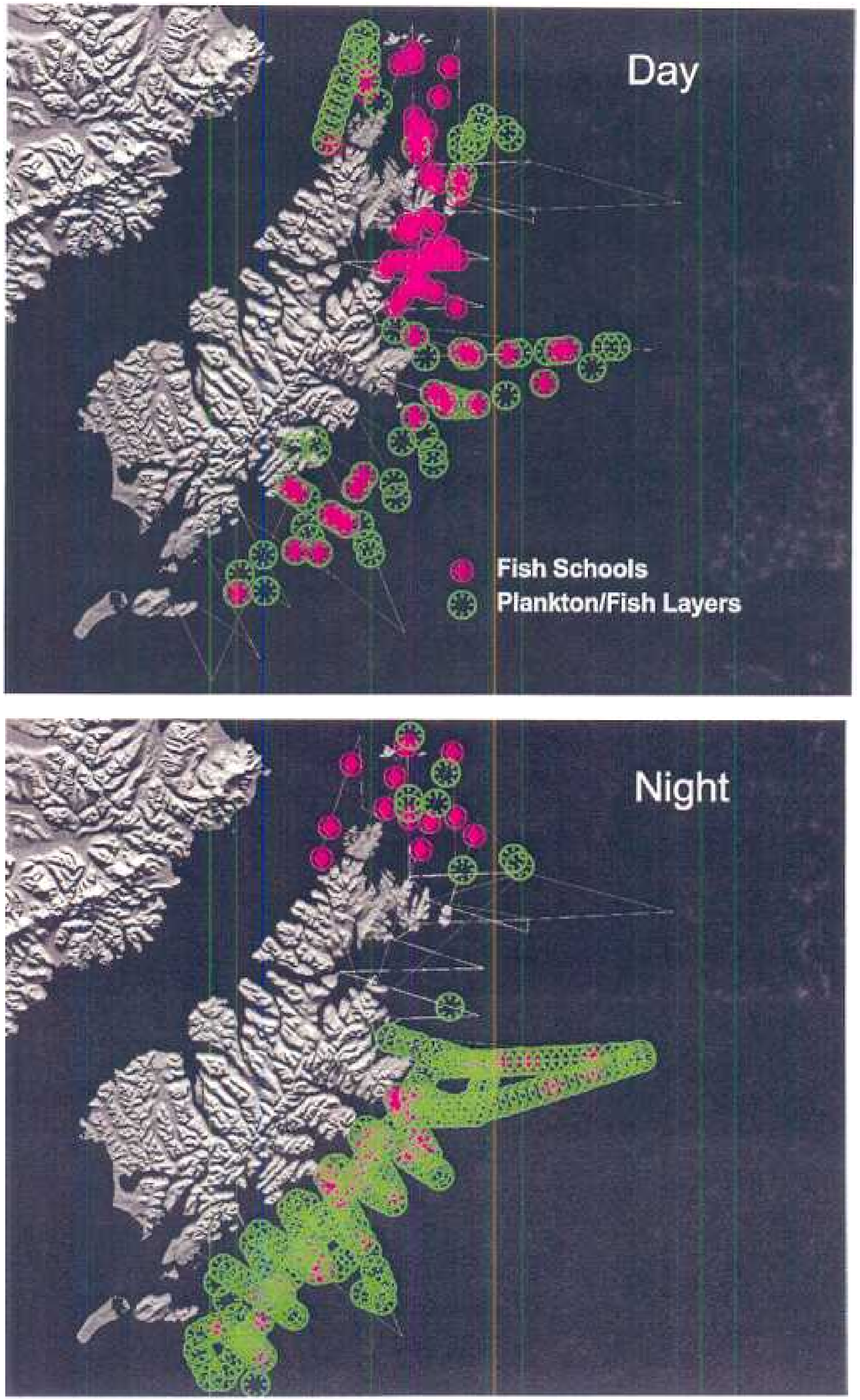

Figure 6. The along track depth penetration (top) of the lidar and integrated signal return through all depths (bottom) during the night survey on August 10, 2001 in Chiniak Gully. The level of the signal is related to the size or density of targets observed.

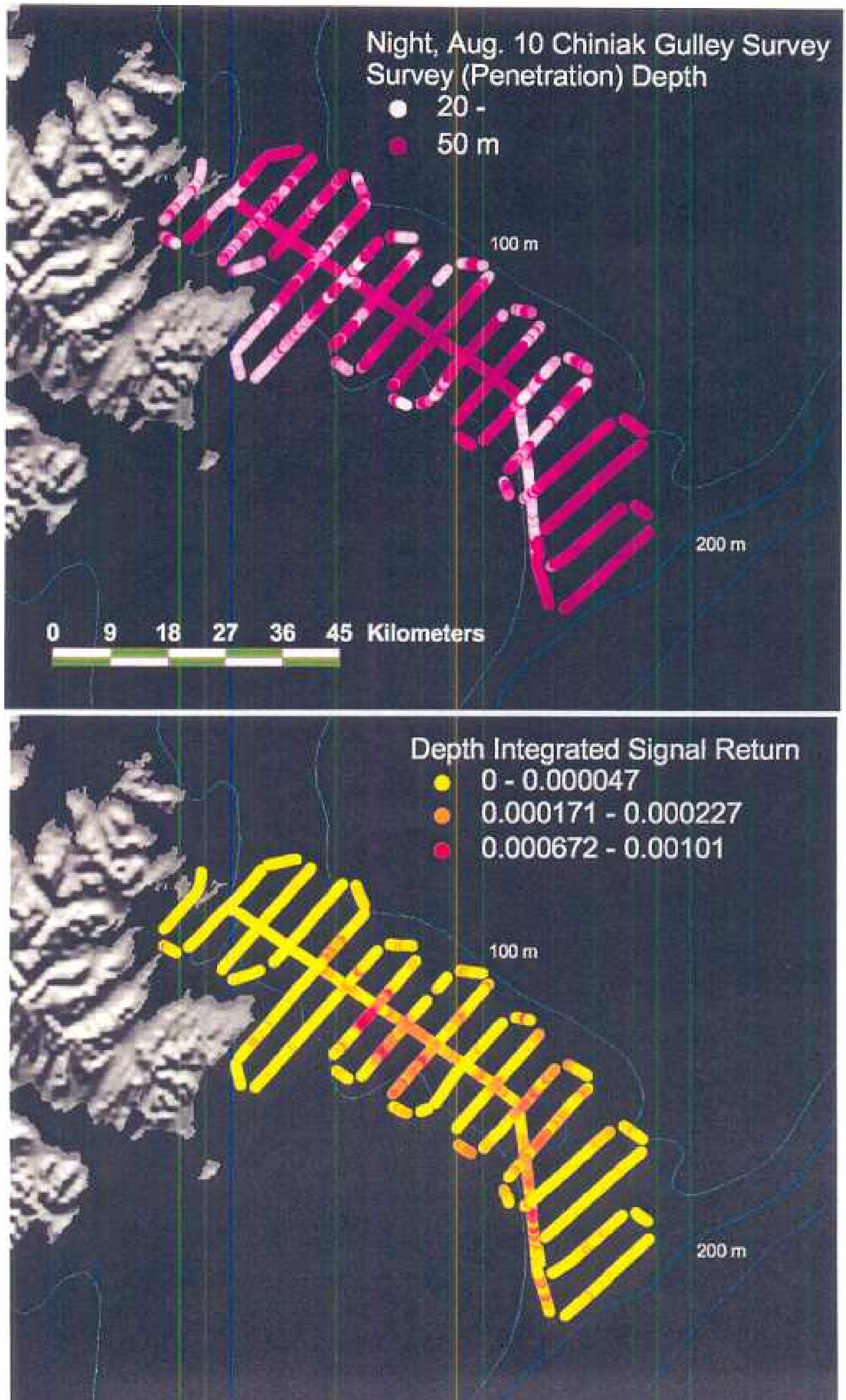

Figure 7. The maximum and average signal by depth at night over the entire survey area on August 10, 2001 in Chiniak Gulley.

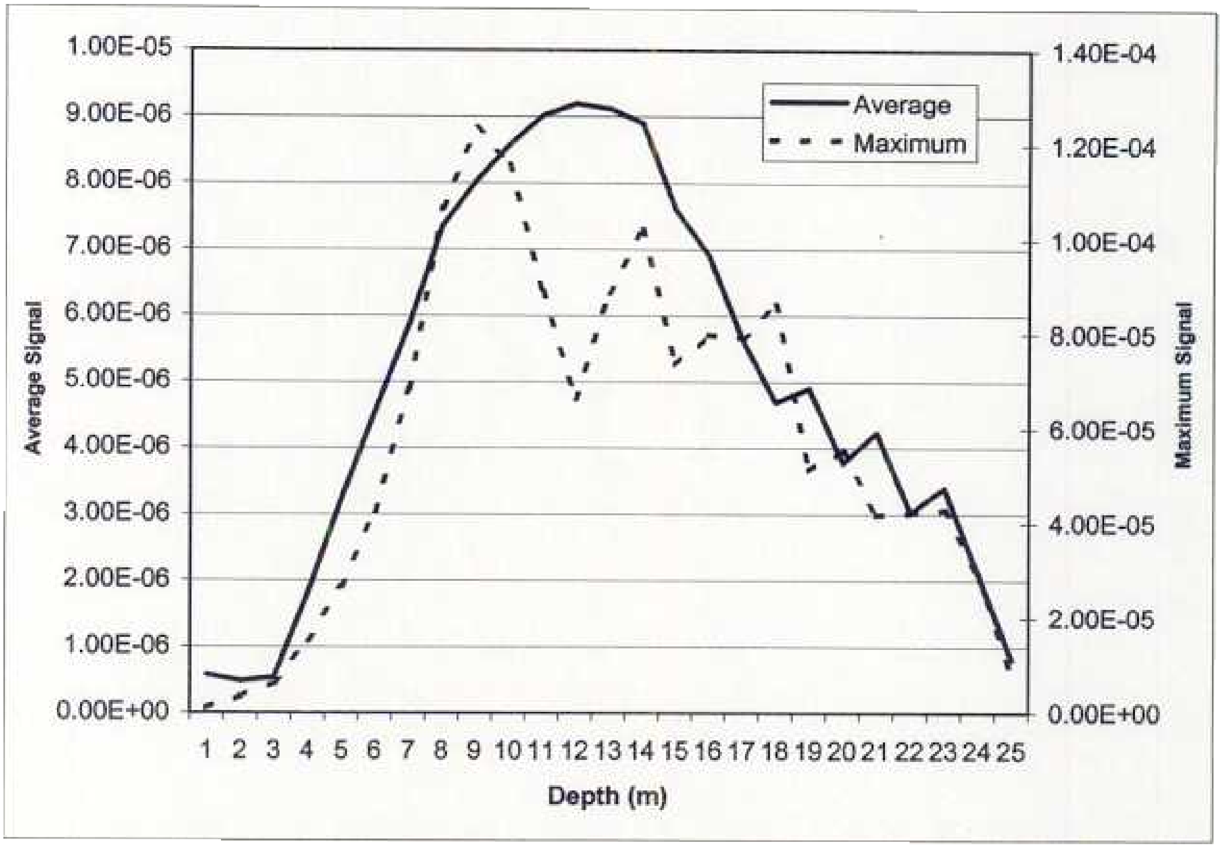

Figure 8. Spatial smoothing of signal intensity during the night survey on August 10, 2001 for the integrated signal between 0 and 25 m (upper right) and the depth specific data at 6, 9, 12, 14, and 18 m. The data was gridded at 1000m blocks and depths were chosen using Figure 6 and the depth at which the first peak maximum signal was observed (9 m), the peak of the mean signal (12 m), the second peak in maximum signal (14 m) and the third peak in maximum signal (18 m).

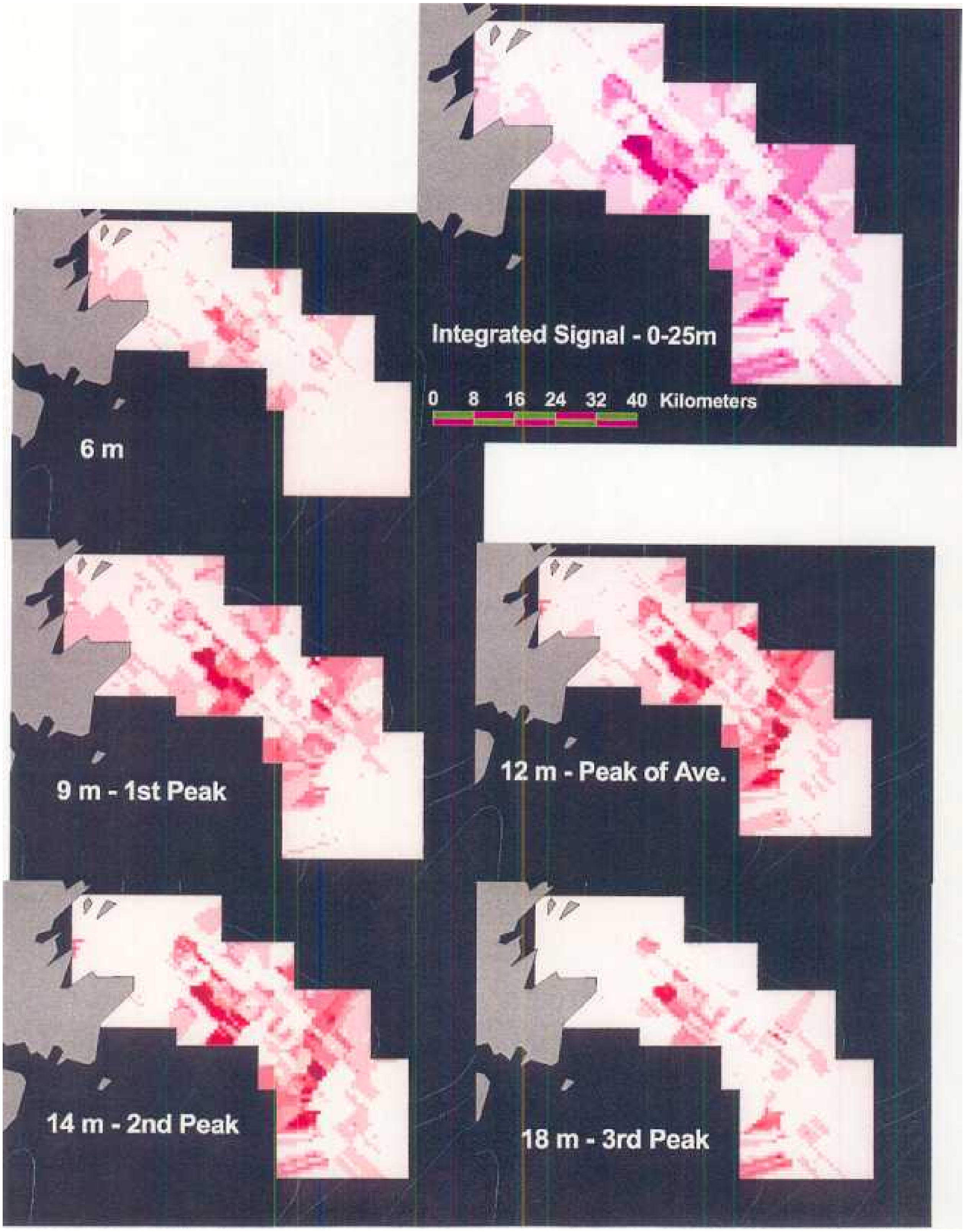

Figure 9. The thermal pattern left in surface waters following the traverse of a baleen whale, in this case either a grey or humpback whale).